ENHANCING K-12 SCIENCE EDUCATION THROUGH A MULTI-DEVICE WEB TOOL TO FACILITATE CONTENT INTEGRATION AND E-INFRASTRUCTURE ACCESS

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Abstract

An effective K-12 science education is essential to succeed in future phases of the curriculum and the e-Infrastructures for education provide new opportunities to enhance it. This paper presents ViSH Viewer, an innovative web tool to consume educational content which aims to facilitate e-Science infrastructures access through a next generation learning object called "Virtual Excursion". Virtual Excursions provide a new way to explore science in class by taking advantage of e-Infrastructure resources and their integration with other educational contents, resulting in the creation of a reusable, interoperable and granular learning object. In order to better understand how this tool can allow teachers and students a joyful exploration of e-Science, we also present three Virtual Excursion examples. Details about the design, development and the tool itself are explained in this paper as well as the concept, structure and metadata of the new learning object.

Keywords: science in education, e-Infrastructure for education, learning objects, virtual excursions

1 INTRODUCTION

As technology evolves, more e-Infrastructures (or cyberinfrastructures) are available for using in education increasing their worldwide access and providing new opportunities to increase student's motivation and engagement while they learn. An e-Infrastructure consists of computational systems, data management, advanced instruments, visualization environments, and people, all linked together by software and advanced networks to improve scholarly productivity and enable knowledge breakthroughs and discoveries not otherwise possible [1]. In education, e-Infrastructures can be used to provide unprecedented access to educational resources including mentors, experts, online activities, games and virtual environments [2]. Also, they provide learners with opportunities to interact with tools of professional science like models, simulations, data sets or remote equipment. Hence, teachers can use e-Infrastructures to expand the educational contents available to students and to provide more engaging experiences. Furthermore, if teachers combine traditional F2F (Face to Face) teaching and virtual components, they can enrich the learning experience in an effective way taking advantage of technology without renouncing to the advantages of frontal teaching in class [3].

However, despite all e-Infrastructure benefits in education, teachers have to use classical resources which provide less engaging experiences. This is because, firstly, they cannot find accessible and appropriate e-Infrastructures in an easy way, and secondly, because to create valuable educational resources we need to integrate the e-Infrastructures with other educational contents like texts, images or videos into a unique learning object.

This is the main problem that we found when started the GLOBAL excursion (Extended Curriculum for Science Infrastructure Online) [4] project. GLOBAL excursion is a European project which main aim is to enrich science teaching in European schools. Via a central web portal, called the Virtual Science Hub (ViSH), we will provide scientists, teachers and their pupils a package of activities, materials and tools for enabling the integration of e-Infrastructures into school curricula. The main tool that we have developed in the GLOBAL excursion project is called ViSH Viewer and will be presented in this paper. The essential feature of this tool is the rendering of Virtual Excursions, a new learning object which will be also presented.

The rest of the paper is organized as follows. The next section reviews related work of e-Infrastructure use in e-Science and education as well as learning objects definition. Section 3 introduces the GLOBAL excursion project. Section 4 explains the Virtual Excursions Viewer tool and the related learning object. Section 5 presents three Virtual Excursion examples, and section 6 finishes with some conclusions and future work.

2 RELATED WORK

During the last years, various e-Science infrastructures have provided services and computational resources to many scientific applications mostly in order to increase research capabilities. Several e-Science infrastructures exist today (e.g. DEISA [5], EGI [6], OSG [7], XSEDE [8]) with the foremost aim of sharing computing resources and data between scientists.

The development of e-Infrastructures for education is in its early stage. However, there are some projects which are working in using and developing e-Infrastructures and applications for enriching e-Learning. For example, the DEISA project, in order to bridge the chasm between education and science, developed an e-School prototype which consists in a virtual laboratory based on an e-Infrastructure and a distributed digital repository for science and engineering applications for students and educators [9][10].

The UK eBank project aims to build links from e-research to e-learning, facilitating the scholarly knowledge cycle through the integration of digital repositories (experimental data, e-prints, and learning objects), and providing aggregator services [11].

Another related interesting project is the CIBER-U (Cyber-Infrastructure-Based Engineering Repositories for Undergraduates) [12] project, which aims to forge a cyberinfrastructure to support undergraduate engineering education with product dissection as unifying theme.

Not all e-Infrastructure resources can be considered adequate to be used in the class or as a learning object. According to the Learning Technology Standards Committee (LTSC) [13] of the Institute of Electrical and Electronic Engineers (IEEE) a learning object is “any entity, digital, or non-digital, which can be used, reused, or referenced during technology supported learning” [14]. So, not all the e-Infrastructure resources match this definition because most of them have been designed to be used in their specific scientific field and by technicians or scientists. But considering that a learning object can be formed by a composition of resources [15] this e-Infrastructure resources can be combined with other explanations (e.g. text or video) to complete them and make them more pedagogical.

3 GLOBAL EXCURSION PROJECT

GLOBAL excursion is a supporting action funded by the European Commission under the Research and Innovation Infrastructures programme of FP7. The project will develop a common understanding, teaching use cases, as well as pedagogical and technical artifacts. The main purpose of the GLOBAL excursion project is to enable students and teachers access to the experimental laboratories and resources of selected e-Infrastructures in order to improve science curricula by enriching school’s existing teaching and learning materials.

The scientific partners participating in the project are initially three, the Institute for Biocomputation and Physics of Complex Systems (BIFI) from Spain, the Nanoscience Centre from the University of Cambridge (UCAM) from the United Kingdom and the Computer and Automation Research Institute (SZTAKI) from Hungary. Other scientific centers are expected to participate in the near future. The materials currently provided by the partners are based on the following topics: biotechnology and life sciences from BIFI, grid and volunteer computing from STZAKI and nanoscience from UCAM.

3.1 VIRTUAL SCIENCE HUB

The web platform where all GLOBAL excursion activities will take place is called Virtual Science Hub (ViSH). It has been designed following a participatory design methodology, where the developers, designers and future users engaged to work together.

ViSH is a social network where teachers and scientists share their resources, know each other and collaborate. It offers a wide variety of functionalities to enhance this collaboration between teachers and scientist, like private messages, a wall to share your thoughts or to share a URL to a webpage that you have found and that you think is very useful. But the main functionality comes with the introduction of Virtual Excursions that we will explain in the next section. ViSH is open source and it is currently in production in http://vishub.org. It is free for end users to register, enter the community and enjoy the experience.

4 THE VIRTUAL EXCURSIONS

The scientific materials that the e-Infrastructures provide are very diverse. However, as they are very technical and specialized they can be difficult to understand for young students. To make these materials attractive and enjoyable for students and to allow the creation of interactive learning multi-device objects, we have introduced the concept of Virtual Excursion.

A Virtual Excursion is defined as a tour through some digital context by teachers and pupils on a given topic that is attractive and has an educational purpose. A Virtual Excursion provides a new way to explore science in class allowing students and teachers to access and control experimental equipment of research laboratories at remote sites, explore natural parks, museums or any other infrastructure with educational or cultural interest which would be too expensive or non-viable to visit in person. To enable these virtual tours the Virtual Excursions use e-Infrastructure resources.

4.1 LEARNING OBJECT

In order to facilitate the Virtual Excursions accessing, sharing, interoperability and reusability [16], they are provided as learning objects (LOs). Sharing LOs across the internet, developed by a few but used by many, enables cost-effective development and deployment of these resources [17]. Another benefit of reusing LOs is the increase of collaboration between organizations.

Learning objects are tagged with metadata to facilitate their searching and retrieval process, helping users to find them across digital repositories. Also, this metadata can be used by recommender systems in e-Learning platforms to find the most suitable LO among all the items available for a specific user taking into account his/her interests [18].

A Virtual Excursion is composed by an arrangement of educational resources of any type: texts, images, animations, videos, websites, flash objects, surveys and quizzes, pdfs or 3D objects. More interesting resources are available in Virtual Excursions: live streamings such as a live webcam of a natural park or the microscope video output of a scientific lab; e-Infrastructure resources which allow, for example, to access and control a real pendulum remotely; and interactive multi-device learning objects designed with K-12 environments in mind like Virtual Experiments [19].

According to [15], as a LO size decreases (lower granularity) its potential for reuse increases, hence in order to enhance the reusing of the LOs in e-Learning contexts, the Virtual Excursions are created as granular LOs with four aggregation levels according to Fig. 1.

- The first level, which corresponds to the most granular or atomic level, includes raw media files like texts, images or videos, and single objects like a website, a flash object or a document. A single quiz, defined by a question and optionally a set of choices and/or the correct answer, also belongs to the first level. Live streamings or e-Infrastructure resources such as the remote pendulum belongs to the first level too, this means that an e-Infrastructure resource can be reused in multiple Virtual Excursions.
- The second level which consists of an aggregation of single elements covers only one LO which we call “slide” due to its conceptual similarity to a presentation slide. The most common visualization of a Virtual Excursion is like a slide presentation. However, we must take into account that Virtual Excursions are not limited to be explored in that way, for example, they can be shown with gaming visualization [20] or like a flashcard.
- There is a third aggregation level which includes any LO that is built as a composition of “slides” like the Virtual Experiments [19].
- Finally, the fourth level corresponds to the Virtual Excursion learning object. Notice that a Virtual Excursion can contain directly a slide without using a LO of the third aggregation level as a wrapper.

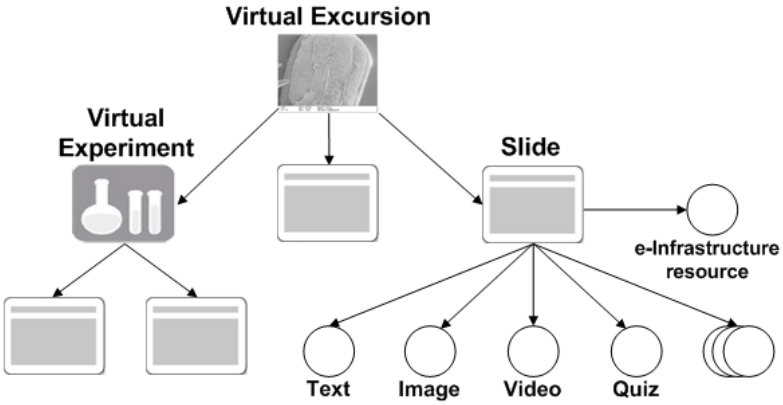

Figure 1. Virtual Excursion aggregation levels

4.2 LEARNING OBJECT METADATA AND STANDARDS

LO metadata is very important since provides information about the object and its possible educational uses as well as facilitating its searching and retrieval process. Virtual Excursions and its metadata are defined in JSON (JavaScript Object Notation) [21] format, which provides a better performance than XML (eXtensible Markup Language) for Rich Internet Applications (RIA) like ViSH Viewer since browsers parse JSON faster. The selection of the language for producing LOs should be performed with the main purpose of achieving interoperability since, according to [17], success depends on the flawless execution of LOs in all operating systems and delivery media. So, JSON is ideal due to JavaScript ubiquitous nature among all the web browsers and the presence of web browsers in almost all modern devices.

In the current version, we are using 11 metadata elements which are Identifier (identifies the excursion inside the ViSH Platform and its associated URL), Title, Description, Author, Language, Avatar (an image to identify the excursion visually), Tags (act as keywords for the ViSH search engine), and 4 more metadata elements related to pedagogical qualities based on LOM (Learning Object Metadata) standard [22] which are Subject, Age Range, Educational Objectives and Acquired Competencies.

Although Virtual Excursions are saved in JSON format, it is possible to export them to a standard e-Learning format such as SCORM (Sharable Content Object Reference Model) [23]. This way the Virtual Excursions can be inserted and used in any Learning Management System (LMS) that is compliant with the standard (which is almost all of them). This is a very important feature as many teachers have in their institution LMS the meeting point with their students, where students have an account and look for the learning resources that the teacher shares. Creating the SCORM object for the Virtual Excursion is quite easy: as the Virtual Excursion is a web resource, we introduce the whole web page in the SCORM zip package and indicate it in the manifest file, so it is available as an iframe when it is inserted in the LMS.

4.3 THE VIRTUAL EXCURSIONS VIEWER TOOL

The Virtual Excursions Viewer tool, which is referred to as ViSH Viewer, is a web application which allows users to view and interact with Virtual Excursions from any device, using only a web browser without any installation or previous configuration being needed. In this section, we will explain the main Virtual Excursions Viewer tool features.

The first feature to consider is the viewing of e-Infrastructure resources integrated with other pedagogical contents. ViSH Viewer facilitates e-Infrastructure access by managing the connections with live streamings and interacting with the web services and the particular interfaces of the e-Infrastructure resources.

The Virtual Excursions can be synchronized through ViSH Viewer. If the teacher shares a Virtual Excursion allowing this functionality, his/her pupils can enter the URL and they will see the same as the teacher. The slides are automatically advanced and the videos are played at the same time. This is very useful for the pupils to follow the explanations from their laptops, tablets or mobile phones. This functionality enables the next one that is integration with videoconference services.

Virtual Excursions are web resources, and so they can be used in any web videoconference tool. Using the synchronization feature we have fully integrated them with a videoconference tool called MashMe.tv (http://mashme.tv). This integration allows many use cases, for example:

- the teacher can share the Virtual Excursion through MashMe.tv, his/her pupils join and can follow the explanations as they see the same as the teacher. Also, they can ask questions and interact in real time. This can be used for small groups of pupils in distance learning or for tutorial classes.
- the teacher can make an appointment with a scientist or other teacher and together can explain the concepts in the Virtual Excursion. For example, the scientist can help the teacher to explain the resources and his/her work, and show the real laboratory and the real facilities.

The integration with other web applications like MashMe.tv is possible because a Virtual Excursion is a web resource that can be embedded in any website, but also because ViSH Viewer provides an API (Application Programming Interface) which allows third web applications to use advanced functionalities of ViSH Viewer such as the synchronization feature explained before.

Another interesting feature is the possibility of doing quizzes in Virtual Excursions. Quizzes allow teachers to evaluate the students acquired competencies to check if the educational objectives have been achieved. Furthermore, quizzes can be self-correcting in order to allow pupils to test their knowledge.

Students can use their own mobile devices or tablets to view the different educational contents, answer the quizzes or perform any other activity in the excursions. However, some resources use technologies that might not be available in a specific device or browser. For example, a flash object cannot be visualized in an iPhone or modern Android device since they not support flash, or an HTML5 [24] video encoded in WebM format cannot be reproduced in Internet Explorer or Safari. In order to deal with these situations, ViSH Viewer has a content adaptation and filter feature which aims to provide the best possible user experience.

Finally, ViSH Viewer provides a functionality to allow offline access to Virtual Excursions. Every time a user accesses an excursion the browser saves it (together with the resources that can be stored offline, like images, texts or videos for example) allowing its future offline access. Hence, when the user comes back to the page, if he/she has no network connection, a page with the offline available excursions will be shown and he/she will be able to enjoy them without consuming any bandwidth.

4.4 TECHNOLOGY AND IMPLEMENTATION

ViSH Viewer is a web application based on HTML5, the new standard for the web. For this reason, any HTML5 compliant web browser can run the web tool and hence render the Virtual Excursions. So, any device with an HTML5 compliant browser allows to explore and to interact with the Virtual Excursions.

Nevertheless, actually HTML5 is not the panacea for developing cross-device web applications since its specification is not yet complete causing that there is no notion of a fully HTML5 compliant browser. Ideally, HTML5 should be device-agnostic, but in practice there are small differences in the HTML5 implementations of the different browsers which cause the need of customizing the HTML5 application for the different browsers and devices. For this reason, several tailored fixes has been developed in order to provide a real multi-device web tool.

ViSH Viewer has been developed as a lightweight JavaScript library and a set of HTML pages and CSS (Cascading Style Sheets) files. It can work as a fully client-side application, however some functionalities, like synchronization or non self-correcting quizzes, needs a server backend. ViSH Viewer is not tied to any specific backend technology, in fact, we have developed two different implementations using Ruby on Rails and Node.js.

5 VIRTUAL EXCURSIONS EXAMPLES

In order to have a better understanding of how this tool can enhance learning and increase students motivation and engagement through the use of e-Infrastructures resources, in this section we present three different Virtual Excursion examples.

5.1 DOÑANA BIOLOGICAL RESERVE

This Virtual Excursion consists of a virtual visit to the Doñana Biological Reserve located in Spain in the provinces of Huelva, Sevilla and Cádiz. The Doñana Biological Reserve was declared World Heritage in 1994 and is considered one of the most important natural protected landscapes in the world. By exploring this Virtual Excursion, students can observe a huge variety of animal species through live webcams accompanied by complementary explanations and media files. In Fig. 2, we can see a live streaming which shows an Iberian Lynx, one of the most endangered cat species in the world.

Figure 2. Live webcam in Doñana

5.2 REMOTE PHYSICS LABORATORY

In the following Virtual Excursion, students will have the chance of accessing and controlling remotely a real pendulum of the remote physics laboratory of the Institute for Biocomputation and Physics of Complex Systems (BIFI) located in Zaragoza, Spain.

A physics exercise is explained at the beginning of the excursion. The students should resolve it and then perform the experiment using the real pendulum in order to compare their theoretical calculations with the measurements of the real system. Instructions to control the remote pendulum are given in the excursion. Finally, a quiz is performed in order to ensure that the student has realized the exercise and the result is stored. The slides that include the exercise and the pendulum are shown in Fig. 3.

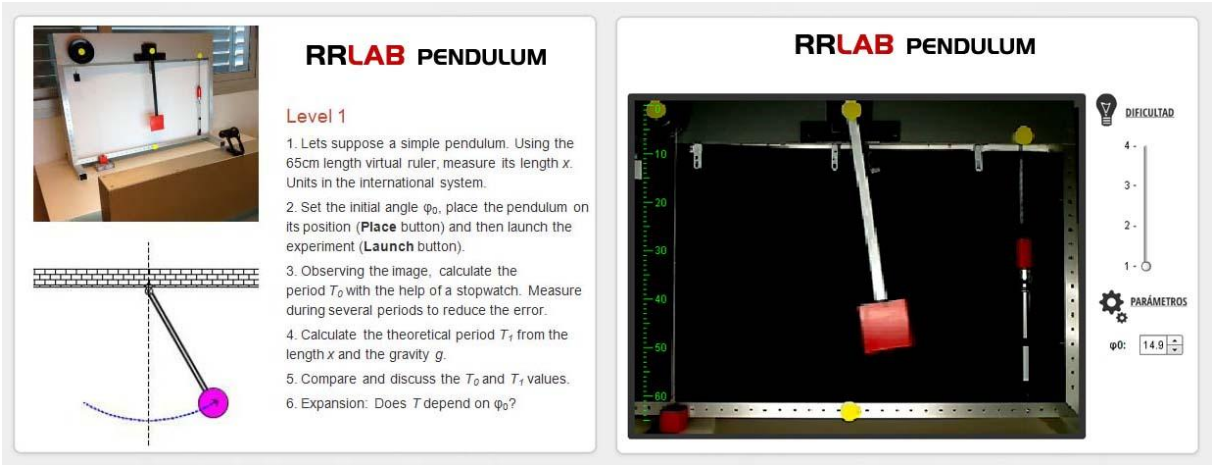

Figure 3. Physics exercise and remote pendulum at BIFI

5.3 REAL TIME MICROSCOPE

The Nanoscience Centre of the University of Cambridge (UCAM) has various microscopes used for research at the Nanoscale, which are extremely precise and expensive instruments.

Through this Virtual Excursion (Fig. 4), teachers and their pupils can observe real time research using these microscopes and receive advice and explanations in real time of the researcher who will be operating the microscope via a videoconference service.

Figure 4. Real time microscope at Nanoscience Centre of UCAM

6 CONCLUSIONS AND FUTURE WORK

In this paper we have presented ViSH Viewer, an innovative web tool to consume educational content. This tool aims to provide new opportunities to increase student's motivation and engagement by facilitating e-Science infrastructures access using Virtual Excursions, a new learning object which concept and structure has also been explained in the paper.

Reusability of learning objects is very important, hence several works have been realized in order to make the Virtual Excursions accessible and reusable, and to provide interoperability with websites, third services and LMS.

Furthermore, we have exposed some examples of how to enrich learning using e-Infrastructures resources by their integration into Virtual Excursions together with other diverse educational contents.

ViSH Viewer is a great example of how technology can enhance learning, but there are many future works that can be performed to bring new contributions in order to keep improving.

The first future work we would like to do is to provide teachers a new web tool which allows them to create its own Virtual Excursions, using for this purpose infrastructure resources, media files or any other educational content provided by scientific institutions, researchers and learning objects repositories, as well as their own resources and materials shared by teachers community.

Another interesting work that appears with the creation of the new LOs, is to develop a web service to facilitate the integration and interoperability of the "slide" LO into diverse fields such as games, smart city guides or even in films and books. This service would provide new innovative ways to access and consume educational contents.

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